Os isotope compositions and fractionation of siderophile elements in metal phases from CB chondrites

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Metal is one of the main components of chondritic meteorites and a significant reservoir of Fe along with silicates and sulfides. Metal plays a key role in physicochemical processes that fractionate siderophile elements from lithophile elements in the early solar system, generating variable chemical reservoirs before the onset of planetesimal formation. Highly siderophile elements (HSEs: Re, Os, Ir, Ru, Pt and Pd) have a great affinity for Fe-metal relative to silicate; HSEs are very refractory and exist as gas only at high temperature. Therefore, HSEs in metals in a variety of meteorites can provide an important clue for understanding of high temperature processes in the nebula. Specifically, the ^{187}Re–^{187}Os isotope system yields chronological information regarding the fractionation of HSEs. Numerous studies have conducted comprehensive analyses of HSE abundances in chondritic metals utilizing laser ablation ICP-MS (LA-ICP-MS) [e.g., 1–2]. However, these studies scarcely include *in-situ* Os isotope data due to analytical difficulties. We have developed a technique for *in-situ* measurement of Os isotopes in metal grains using a micro-milling system coupled with N-TIMS. Our previous study reported that individual CB metals have ^{187}Os/^{188}Os ratios close to the bulk CI chondrite value with limited variation [3]. This study is a follow up of our previous investigation that places emphasis on spot analyses of HSEs and other siderophile elements in CB metals where ^{187}Os/^{188}Os ratios have been obtained. We utilize fs-LA-ICP-MS for conducting precise HSEs analysis in metal samples. By integrating overall measurements, we discuss the origin of metal grains in different types of CB chondrites.
We examined multiple metal grains in three CB chondrites: Bencubbin (CB_a), Gujba (CB_a), and Isheyevo (CB_b). The details for Os isotope analysis using a micro milling system and N-TIMS are described in [3]. The concentrations of P, S, Cr, Fe, Co, and Ni in analytical spots adjacent to the sampling pits for Os isotope analysis were determined by EPMA (JEOL-JXA-8530F). The concentrations of HSEs in analytical spots adjacent to the sampling pits were analyzed with fs-LA-ICP-MS (IFRIT, Cyber Laser).
Our Re–Os isotope data are mostly plotted on the 4.567 Ga Re–Os reference line. Nearly homogeneous ^{187}Os/^{188}Os ratios in CB metals indicate that fractionation of Re and Os was minuscule during metal formation at ~4.57Ga. Because Re and Os are ultra-refractory elements with similar 50% condensation temperatures (Re: 1821 K, Os: 1812 K), the limited Re/Os variation may suggest simultaneous condensation of Re and Os from the nebular gas during metal formation. The limited Os isotopic variation suggests that the redistribution of Re and Os during metal formation associated with planetary collision was not significant as are the cases of solidification of liquid metal. A positive correlation of Re/Os ratios calculated from the ^{187}Os/^{188}Os ratios and Os/Ir for CB_a metal grains suggests that the condensation of CB_a metal grains occurred at an equilibrium condition in a cooling gas until the condensation temperature of Ir (~1600 K). Unlike ultra-refractory HSEs, Pd/Fe and Ni/Fe ratios in CB_a and CB_b metals exhibit a strong positive correlation. This positive correlation cannot be explained by nebular condensation but condensation in extremely high gas pressure (10^7 x solar nebula).
References: [1] Jacquet E. et al. (2013) Meteorit. Planet. Sci. 48, 1981–1999. [2] Campbell A. et al. (2002) GCA 66, 647–660. [3] Nakanishi N. et al. (2013) LPSC, abstract #2407.

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